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# Program Accreditation and the Graduate Reference Curriculum in Systems Engineering (GRCSE™)

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**Abstract.** This paper discusses the possible use of the Graduate Reference Curriculum for Systems Engineering (GRCSE) to inform engineering accreditation efforts. The paper is organized as follows: The first section provides background on the genesis of GRCSE. The second section discusses the status of accreditation of systems engineering in the United States and Europe. The third section discusses the objectives, outcomes, and core body of knowledge contained in GRCSE. The last section concludes with a discussion of how the GRCSE work might be expected to influence future accreditation.

## Background

In 2009, the Department of Defense (DoD) funded the Systems Engineering Research Center (SERC) - a DoD University Affiliated Research Center (UARC) - for a three-year project called the Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE™). There were two major deliverables: a Systems Engineering Body of Knowledge (SEBoK), and GRCSE. BKCASE relied primarily on volunteer authors funded by their parent organizations, and the author team consisted of about 70 authors from every continent but Antarctica. The third draft of the SEBoK was released for public comment in March 2012.

GRCSE is being written by 14 of the BKCASE authors. A preliminary draft was released for limited review in December 2010. A second draft of GRCSE (GRCSE V0.5) was released for public comment in December 2011, and the final version is scheduled for release in December 2012.

At the time of this writing, stewardship for both the SEBOK and GRCSE will pass upon final release to a partnership of the International Council on Systems engineering (INCOSE) and the Institute for Electrical and Electronics Engineers (IEEE) Computer Society.

GRCSE 0.5 contains nine chapters and six appendices. (Pyster and Olwell, 2011) The chapters include an introduction, context, objectives, outcomes, entrance expectations, curriculum architecture, core body of knowledge (CorBoK), assessment, and evolution. The appendices cover a survey of existing programs, background on Bloom's taxonomy, a mapping of the CorBoK to the outcomes, a summary of competency based curriculum, and a set of use cases.

The front matter to GRCSE states:

*GRCSE is not intended to be used to score, appraise, accredit, or certify programs for compliance. Phrases such as “GRCSE-compliant” are not used herein. Instead, the terms “satisfies GRCSE recommendations” or “aligns with GRCSE recommendations” periodically appear. Given the flexibilities built into GRCSE, the latter term is not rigidly defined, but is intended for a program that follows most GRCSE recommendations. (Pyster and Olwell, 2011)*

Accreditation serves different needs in different countries. These disparate needs are not, again, specifically addressed in GRCSE. The nature of GRCSE as providing recommendations precludes GRCSE from being used directly as a tool against which to accredit programs. Therefore any program accreditation agency would need to develop its specific accreditation criteria.

Since the BKCASE project began, a paper by Chittister and Haimes has appeared arguing that ABET, INCOSE, and IEEE should:

*(a) harmonize and solidify the specific requirements for the accreditation of systems engineering programs in colleges and universities in the United States and abroad, and (b) guide the development of BoK requirements for any certification of systems engineers beyond the baccalaureate level. Chittister and Haimes (2011)*

This paper discusses how GRCSE can enable ABET, INCOSE, and IEEE to do so.

There is not consensus in the community about the need for accreditation of graduate programs. This was evident in the panel discussion on Accreditation at the 2011 INCOSE International Symposium. (Olwell, 2011) While there was agreement on the need to accredit undergraduate programs as a precursor to professional licensure, opinions differed on the value of doing so for graduate programs. One group thought that the effort outweighed the return. A second group did not want to restrict admissions into programs by requiring students to meet the ABET undergraduate requirements. A third group thought that accreditation was essential to assure quality and to build the status of the profession as an engineering discipline. There was a lively floor debate on the topics.

GRCSE was not designed for specific use as an accreditation instrument. However, its content can support the design of such an instrument.

## **The Status of Accreditation of Systems Engineering Programs in the United States and elsewhere**

In the United States, engineering programs are accredited by ABET. Systems engineering programs have been accredited since 1970, when the undergraduate program at the United States Naval Academy was accredited. Thirteen undergraduate SE programs are currently listed by ABET as accredited, along with three programs - two at the Naval Postgraduate School (NPS), one at the Air Force Institute of Technology (AFIT) - at the graduate level.

There are no program-specific ABET criteria for systems engineering. That is, there are no additional requirements beyond those in the general criteria for any engineering curriculum. This contrasts with other engineering disciplines, such as mechanical or electrical engineering,

for which ABET has identified unique criteria for accreditation. (ABET Engineering Accreditation Commission, 2011) Part of the reason for this is that ABET SE accreditation currently falls under the cognizance of six different professional societies, with competing visions and interests. Those societies are the American Society of Mechanical Engineers, the IEEE, the Institute of Industrial Engineers, the International Society of Automation (ISA), INCOSE, and SAE International.

Because of the Washington Accord, engineering programs accredited by one participating country are generally recognized by the others.

In the United Kingdom, the Institution of Engineering and Technology accredits engineering programs. (2011) There is one program listed at the undergraduate level and one at the master's level for systems engineering, although there are many other domain-centric systems engineering programs (such as computer systems engineering or communications systems engineering.) (Fabryky, 2010)

In Australia, there is one undergraduate program in systems engineering accredited by Engineers Australia, and no graduate programs. (Engineers Australia, 2011)

In Canada, one undergraduate program (University of Regina) in systems engineering was accredited from 1982-1985 by Engineers Canada, but none are currently. (Engineers Canada, 2011)

In Taiwan, there are no undergraduate programs accredited in systems engineering. There is one program in Industrial and Systems Engineering at Chung Yuan Christian University accredited at both the undergraduate and graduate levels by the Institute of Engineering Education Taiwan. (IEET, 2011). Taiwan has no discipline specific criteria for systems engineering.

In Hong Kong, there is one undergraduate program in Systems Engineering and Engineering Management accredited by the Hong Kong Institution of Engineers (HKIE). (HKIE, 2011)

In Ireland, there is no accredited program in systems engineering. (Engineers Ireland, 2011)

In South Africa, there are no programs in systems engineering accredited by the Engineering Council of South Africa. (Engineering Council of South Africa, 2011).

In general, we can see that few systems engineering programs worldwide are accredited by their national accrediting body. The authors could find no program specific criteria for systems engineering accreditation anywhere in the world.

Graduate accreditation by ABET requires that a program demonstrate that its graduates have also met the undergraduate ABET requirements. For programs that admit students without an ABET undergraduate degree, this can require significant effort to verify and document.

### **Objectives, Outcomes, and Core Body of Knowledge in GRCSE**

In the United States and in other countries that follow its accreditation protocols, ABET requires a program to define program educational objectives and student outcomes. Program objectives are, "broad statements that describe what graduates are expected to attain within a few years of graduation. Program educational objectives are based on the needs of the

program's constituencies." (ABET, 2011a) Student outcomes are, "Statements that describe what students are expected to know and be able to do by the time of graduation. These relate to skills, knowledge, and behaviors that students acquire as they progress through the program." (ABET, 2011b)

GRCSE has followed this framework in its approach. In particular, it includes a chapter on objectives with 4 objectives and a chapter on outcomes with 13 recommended outcomes recommended for consideration by all SE master's programs. These recommendations are not meant to be prescriptive, but rather to provide a benchmark.

Of particular note is that the first recommended outcome is, "Achieve designated Bloom's levels of attainment for each SEBoK topic contained within the core foundation." This outcome refers to what is known as the core body of knowledge (CorBoK) for GRCSE. It is a listing of the topics in the SEBoK, along with a specified Bloom level of attainment.

GRCSE divides the CorBoK into two parts: a foundation that applies to all students, and a set of core extension focus areas. Each student is expected to select one of the extensions. So the second outcome reads, "Achieve designated Bloom's levels of attainment for each SEBoK topic contained within one of the core extension focus areas, as appropriate for the type of master's program or for an individual student's interest."

By design, the CorBoK accounts for about half of the contact hours in a graduate program, leaving the other half for tailoring of content to individual program emphases.

The CorBoK is a very important part of the GRCSE, and is an attempt to generate a level consistency in content across all graduate SE programs. The authors of GRCSE found in their survey of existing graduate programs that there was a very wide variation in the content of existing programs, and that this variation was confusing to students and employers.

## **GRCSE and Accreditation**

As stated earlier, there are only two institutions in the US with ABET accredited systems engineering programs at the graduate level, one in the United Kingdom by IET, and one in Taiwan by IEET. There is not consensus across the SE community as to whether or not accreditation is desirable at the graduate level. However, the authors of this paper argue that accreditation of SE graduate programs is desirable for assuring quality, standardizing content, and most importantly, enhancing the prestige of systems engineering as an engineering discipline.

There are several dozen graduate programs in systems engineering in the United States, many offered part-time and to non-resident students. The quality of many of the programs is unknown, since they do not undergo any external review. External accreditation assures the school, the student, and the employer that the program is meeting a published standard.

The content of programs in systems engineering varies widely. One of the appendices in GRCSE details the results of a survey as to program content. There is enormous variation in the content that is considered required for a systems engineering graduate degree. This is a source of confusion for employers, who cannot make any assumptions about what the holder of a graduate degree in systems engineering knows.

Finally, systems engineering is a new discipline, and still encounters skeptics in the other engineering fields.

Chittister and Haimes (2011) argue:

*As a starting point, accreditation at the baccalaureate level and professional certification post the baccalaureate level constitute a social–professional compact between the certifying professional entities and the public. In this compact, the professional accrediting and certifying entities assure the public of adherence to a scrupulous process, and that all required competencies, BoK, and experiences (as appropriate) have been met.*

Absent accreditation, there is no public assurance. GRCSE can assist programs with accreditation efforts in several ways.

First, it can be used as a benchmark for programs as they set objectives and outcomes. GRCSE lists four representative objectives, and thirteen outcomes. They are designed to allow for tailoring by individual programs. The survey of existing graduate programs conducted by the GRCSE authors and documented in GRCSE shows that only three graduate programs in the survey responded that they had program objectives. The emphasis on objectives in GRCSE and how they are set in consultation with stakeholders strengthens a program. Similarly, the student outcomes listed in GRCSE can be useful to check to see if content is missing or underemphasized in a given program. The specification of Bloom's levels and estimated classroom hours is extremely helpful in this context.

Second, the chapter and appendix on assessment can be used to document the continuous improvement processes required by accrediting bodies. Many programs find that documentation effort for accreditation to be difficult. GRCSE provides techniques that can be useful.

Third, the CorBoK can be used as a benchmark to see if the content of the program contains sufficient systems engineering content by breadth and depth. This is perhaps the biggest contribution. Chittister and Haimes (2011) said:

*A partnership between ABET and the two major professional societies—INCOSE and the IEEE—would achieve a fundamental result: An agreement on what constitutes a BoK in systems engineering at the baccalaureate level would provide invaluable guidance to colleges and universities that offer such degrees. Although such an initiative would not necessarily imply that every undergraduate program in systems engineering would adopt the entire proposed BoK, it would provide a valuable benchmark that ultimately could become the gold standard.*

GRCSE has provided this BoK and benchmark for graduate programs.

GRCSE can also assist with the setting of program criteria. For ABET, GRCSE can provide a starting point for the discussion among the six engineering professional societies as to the identification of appropriate program criteria. The same will be true for other national accrediting bodies. In addition, while GRCSE is focused on graduate programs, it may still prove a useful reference for the development of accreditation criteria specific to undergraduate programs in SE.

Such program criteria need not be as exhaustive as the full GRCSE recommendation. For example, mechanical engineering programs have ABET program criteria that are very broad:

*These program criteria will apply to all engineering programs including "mechanical" or similar modifiers in their titles.*

*1. Curriculum*

*The curriculum must require students to apply principles of engineering, basic science, and mathematics (including multivariate calculus and differential equations); to model, analyze, design, and realize physical systems, components or processes; and prepare students to work professionally in both thermal and mechanical systems areas.*

*2. Faculty*

*The program must demonstrate that faculty members responsible for the upper-level professional program are maintaining currency in their specialty area.*

Similarly, the electrical engineering criteria are fairly broad:

*These program criteria apply to engineering programs that include electrical, electronic, computer, or similar modifiers in their titles.*

*1. Curriculum*

*The structure of the curriculum must provide both breadth and depth across the range of engineering topics implied by the title of the program.*

*The curriculum must include probability and statistics, including applications appropriate to the program name; mathematics through differential and integral calculus; sciences (defined as biological, chemical, or physical science); and engineering topics (including computing science) necessary to analyze and design complex electrical and electronic devices, software, and systems containing hardware and software components.*

*The curriculum for programs containing the modifier "electrical" in the title must include advanced mathematics, such as differential equations, linear algebra, complex variables, and discrete mathematics.*

*The curriculum for programs containing the modifier "computer" in the title must include discrete mathematics.*

Program criteria for systems engineering under ABET could be similarly worded, if the six lead professional societies could agree. In particular, the SE program criteria could specify specific program content and faculty qualifications, as do the two examples noted above.

Any society or accrediting body that wishes to do accreditation of systems engineering programs would need to construct their own accreditation documentation and criteria, and could usefully use GRCSE as one of the sources. In addition, they would also need to incorporate material from the accreditation policy of their organization and material specific to the national or regulatory environment of the institutions which they seek to accredit.

It bears repeating that GRCSE was not explicitly designed to be an accreditation tool. However, GRCSE represents a multinational effort to set reference standards for systems engineering education. As such, it will continue to be relevant for systems engineering accreditation.

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## Biographies

### James Anthony.

James F. Anthony Jr. (Jim Anthony) is a Senior System Engineer supporting the Office of the Deputy Assistant Secretary of Defense for Systems Engineering (ODASD(SE)). He has 29 years engineering experience with the U.S. Air Force, U.S. Navy, Defense Threat Reduction Agency, and DoD Modeling and Simulation Coordination Office. He is "Qualified in Submarines" and a retired U.S. Navy Commander. He has a B.S. in Chemical Engineering,



Magna cum Laude, (1981) from Christian Brothers University and a M.S. in Systems Engineering from George Mason University (2006).

**Stephanie Enck.**

Stephanie Enck is a research assistant at the Naval Postgraduate School's Systems Engineering Department. Her research interests and project coordination efforts for the department stem from working on various SE education initiatives and the BKCASE effort. The combination of these projects has her engaged in communication outreach, intellectual property management, budgeting, and co-management of various online project tools. She has a Bachelor of Science in Communication, successful sales and marketing management experience, and served as a volunteer for the Army community before joining the NPS SE department in 2007.

**Nicole Hutchison.** Ms. Hutchison is a Staff Researcher for the Systems Engineering Research Center (SERC), supporting the Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE) project, specifically wiki implementation, and a technical leadership initiative for the Defense Acquisition University. Prior to joining Stevens, Ms. Hutchison spent five years at Analytic Services Inc., supporting initiatives of the Departments of Defense, Homeland Security, and Health and Human Services as well as the National Guard and the Pacific Air Forces (PACAF). Ms. Hutchison also served at the Louisiana Family Assistance Center in Response to Hurricane Katrina. Ms. Hutchison holds an ME from the Stevens Institute of Technology, an MS from Georgetown University, and a BS and a BA from Virginia Tech.

**David H. Olwell.** Dr. David H. Olwell is Professor of Systems Engineering at the Naval Postgraduate School. Dr. Olwell holds a Ph.D. in Statistics and an M.S. in Mathematics and in Statistics from the University of Minnesota. He is immediate past chair of the Department of Systems Engineering at the Naval Postgraduate School.

Dr. Olwell is a 2011-2012 American Council on Education (ACE) Fellow placed at the University of Hawaii. He is also the co-Principal Investigator of the Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE) project.

**Art Pyster.** Dr. Pyster has more than thirty years of experience as a successful executive, researcher, engineer, educator, and manager in government, industry, and academia. He has created, delivered, acquired, or operated numerous leading edge systems and technologies in telecommunications, aerospace, defense, air traffic control, and information technology domains. Currently, Dr. Pyster is Deputy Executive Director of the DoD Systems Engineering Research Center (SERC) (since 2008), a University Affiliated Research Center. Currently, he leads the Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE) project. He also serves as a Distinguished Research Professor at Stevens Institute of Technology (since 2007), where he teaches and conducts research on systems engineering, software engineering, and enterprise systems. Dr. Pyster is also the Director for Academic Matters for the International Council on Systems Engineering (INCOSE) (since 2010), a member of the INCOSE Board of Directors (since 2008), and an INCOSE Fellow.

**Alice Squires.** Dr. Squires recently completed her doctoral studies at Stevens and is on the faculty in Systems Engineering in the School of Systems and Enterprises at Stevens Institute of Technology. She has over 28 years of experience. After completing her Electrical Engineering bachelor's degree at the University of Maryland, she served as a technical lead for IBM, completed her MBA from George Mason, served as a senior systems engineering manager for both Lockheed Martin and General Dynamics (GD). Next, she served as a Senior Systems Engineer consultant to Lockheed Martin, IBM, and EDO Ceramics, for ASSETT. Dr. Squires holds INCOSE CSEP, CSEP-Acquisition certifications